IQP-52-DSA-9458
IQP-52-DSA-0387

DNA FINGERPRINTING

An Interactive Qualifying Project Report

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

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August 27, 2010

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ABSTRACT

The purpose of this project is to survey the application, evolution, and social implications of DNA fingerprinting technology. Proper methods of collecting, handling, and storing DNA evidence will be described, along with several recent advances in the field. An investigation into the progression of policy regarding the use of DNA fingerprinting as evidence in court cases since its inception will be described, from the first general acceptance standard of *Frye v. US*, to the current five-prong standard of *Daubert v. Merrell Dow*. The uses, and moral and ethical implications of DNA databases will be discussed. Finally, the authors will put forth their own view points about DNA fingerprinting technology.

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PROJECT OBJECTIVES

This project endeavors to examine new technological advances in DNA fingerprinting technology and the societal consequences of those advances. Chapter one attempts to provide an overview of DNA fingerprinting and the methods used for analysis. Chapter two covers proper techniques and modern advances in DNA collection and storage. Chapter three documents landmark cases and how they affected the evolution of which evidence is considered admissible in US courts, and the establishment of various standards for judging DNA evidence. Chapter four discusses the purposes of, and ethical concerns related to, DNA databases. Finally, the authors will discuss their own conclusions on this controversial technology based on the project research.

Chapter-1: DNA Fingerprinting, Description and Types

Harry Moreno

DNA fingerprinting is an immensely useful tool to modern society. The concept of uniquely identifying a person through something he cannot control can arguably be traced back to traditional fingerprints. This "fingerprint" concept is so powerful in forensics that we still use it to describe our use of DNA profiling to create a unique pattern. A piece of information more unique than your name or your social security number, a DNA fingerprint is compiled from the cellular instructions that make you who you are. We can collect DNA from almost any cell, and we have many techniques for analyzing it, depending on the circumstances and goals. Similarly, we have many applications for this technology in forensics, paternity disputes, archeology, identifying unknown remains, and other applications we have yet to discover. The purpose of this chapter is to discuss this new technology, as a prelude to going beyond the methodology in our subsequent chapters on landmark court cases and ethics.

DNA Terminology

To better understand DNA fingerprinting, we must first understand DNA. All living tissue is composed of small units called *cells*. These cells have a specialized function to perform; for example, we can expect a blood cell to perform a different job than say a muscle cell. However, all the cells of a single person (except for red blood cells that have no nucleus) carry a copy of DNA unique to that person. When cells replicate, they make sure to create a faithful copy of the DNA so the resulting daughter cells always have the same DNA. Thus, whether we

gain our forensic DNA sample from a persons' skin or hair does not matter; the tests we use should produce the same fingerprint unique to that person.

Deoxyribonucleic acid (DNA) (**Figure-1**) carries all the instructions used to construct other components of cells. This DNA is composed of four base pairs of chemicals – Adenine (A), Cytosine (C), Guanine (G) and Thymine (T) (blue, green, yellow, red in the figure) – which always link together in the same way – Adenine with Thymine, and Cytosine with Guanine – forming the famous double-helix shape (coiled structure, right side of figure). The vast majority (99.9%) of DNA is actually identical between all humans, coding for those properties that make us human beings. We differ by only 3 million base pairs of DNA - about 0.10 percent of the entire genome (Guide to the Draft Human genome, 2001), and this DNA is tested during fingerprinting.

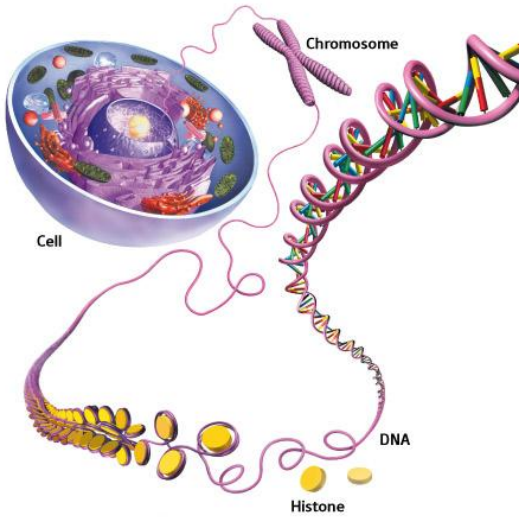

Figure-1: Diagram of a Cell. Note the cell nucleus (center of the cell), containing chromosomes (purple), which contain DNA (purple strand), that exists in a double helical structure (coil on diagram right) (How do cells read genetic information, 2008)

Chromosomes (shown as purple in the figure) are structures composed of DNA and histones. If the DNA from a single cell were laid out, it would be about 1.8 meters in length.

Instead the DNA is tightly coiled around proteins called histones. The resulting structure we refer to as a chromosome. Chromosomes usually form into either x, y or v shapes. Humans have 46 chromosomes (23 from each parent). Those 46 chromosomes are copied into each new cell and provide instructions for everything cells do. Chromosomes are housed in the cells' *nucleus*. The function of the nucleus is to maintain the integrity of the chromosomes and to control the activities of the cell by regulating gene expression. Gene expression is the process by which the information in DNA is used to synthesize a functional gene product – often proteins.

Aside from nuclear DNA, there are two other types of forensic DNA – Y-chromosome and mitochondrial. Y-chromosome DNA is only found on the male sex (Y) chromosome, and is passed on from fathers to sons through the paternal bloodline. As such, a man, his brothers, father and male sons, all have identical Y-DNA. Y-DNA testing is extremely useful where a sample with a high level of female DNA is mixed with a lower amount of male DNA. The female DNA can be "ignored" revealing only the male DNA. If nuclear testing was done on the same sample, the female DNA might mask any other profile present.

Mitochondrial DNA (mtDNA) is found in the mitochondria (part of the cell that produces energy), and not the nucleus of a cell. Mitochondrial DNA is passed through the maternal bloodline, and all maternally-related family members have identical mitochondrial DNA. Comparisons can be made using a reference sample from any maternal relative. Mitochondrial DNA testing is primarily performed on hairs, bones, very old remains, and remains that are severely degraded.

13 Core Loci, STRs, and VNTRs

To create a DNA fingerprint, it is only necessary to look at areas of the genome which vary between individual humans. The FBI has chosen 13 loci (locations) along the genome which do not code for any genetic characteristics. Because these sites differ between individuals we can use it to create fingerprints that allow us to identify the owner. However, it is very important to note that these locations do not provide any personal information such as genetic predispositions. When analyzing all 13 loci, the likelihood that any two individuals (except identical twins) will have the same 13-loci DNA profile is about one in a quintillion (1 followed by 18 zeros) (DNA Profile Probability, 2010).

The DNA at these loci repeat the same pattern of base pairs a variable number of times. These areas are allowed to have much variation between humans because they are non-coding – they make no contribution to the health or survival of the organism. By comparison, if a change occurs within an essential gene - preventing it from working properly - the organism will be strongly disadvantaged and probably not survive, effectively removing that altered gene from the population (Trendy Science, 2007).

There are two types of repeat sequences, STRs and VNTRs. When 2 to 16 basepairs of DNA are repeated we refer to the area as a microsatellite or short tandem repeat (STR). When the number is not known, variable or irrelevant, it is called a variable number tandem repeat (VNTR). For example, a repeat sequence could be ACAG. The locus analyzed would then have the sequence repeat two or more times. These repeat sequences are sandwiched between coding regions of DNA. For either STRs or VNTRs, when we fingerprint the locus we are concerned with the number of times the sequence repeats itself in a particular sample of DNA, this is what differentiates one person from another.

DNA Fingerprinting Types, RFLPs and PCR

But how do we analyze these repetitions? We have two main techniques for creating DNA fingerprints: RFLPs and PCRs.

Restriction fragment length polymorphism (RFLP) is a molecular biological technique used to analyze VNTRs that result from the digestion of a DNA sample with a special enzyme, a restriction endonuclease. Restriction enzymes cut DNA at specific sequences. The enzyme will recognize the pattern and cut the DNA where the pattern starts and ends; producing fragments of different lengths depending on how many times the particular pattern was repeated in the DNA. These fragments are then separated using gel electrophoresis (**Figure-2**) and hybridized with DNA probes that bind to a complementary DNA sequence within the sample.

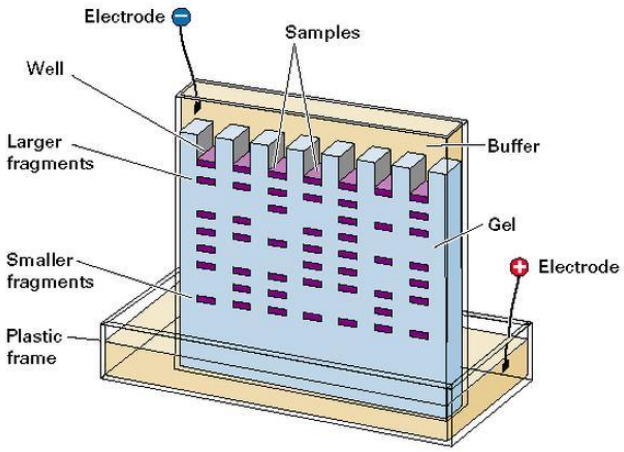

Figure-2: Diagram of DNA Electrophoresis During RFLP Analysis. Note that the smaller fragments move faster through the gel, so migrate farther. DNA is negatively charged, so migrates towards the positive anode. (The Molecular Structure and Replication of Genetic material, 1998)

The electrophoresis exerts an electromotive force which moves the DNA fragment through the gel. Basically, longer fragments will travel less distance through the gel than shorter fragments, as they have a harder time sieving through the gel. The distance traveled roughly tells

us the number of times the VNTR was repeated. We then show this graphically by taking a picture of the gel if we stained the probe molecules beforehand or if the molecules fluoresce under ultraviolet light (Gel Electrophoresis, 2010). In either case we produce a picture that shows DNA fragments and their sizes, which can be compared for various samples. If the markers match we have very good odds they represent the same person.

RFLP is the older of the two techniques. It is considered to be the more accurate of the two tests; it is very conclusive and is more resilient against contamination. So RFLP is the preferred method if sufficient DNA is available. Unfortunately, RFLP requires more DNA than PCR, such as several strands of hair or at least 15 µl of blood (The Human DNA, 2010). If several samples are mixed together, e.g. multiple rapists, you do not get a clear fingerprint. And the RFLP test can take anywhere from three weeks to three months to complete.

The second type, polymerase chain reaction (PCR) amplifies a single or a few copies of a piece of DNA across several orders of magnitude, generating thousands to millions of copies of a particular DNA sequence (**Figure-3**). First, the unknown DNA is heated, which causes the paired strands of the double helix to separate. The second step is to add a large excess of primers (gray in the diagram), strands of nucleic acid that serve as a starting point for DNA synthesis, and cool the reaction mixture to allow the double-strands to form again. The third step involves elevating the temperature to about 72°C the optimization temperature for Taq Polymerase, an enzyme that can synthesize DNA at elevated temperatures. Taq uses a mixture of precursors (A, C, G, and T) to add them to the elongating DNA strand using the primers to initiate the reaction. Repeating this cycle about 35 times (denaturation, primer annealing and elongation) will result in plenty of DNA, all of it representing copies of the original region (Brown, 2006). Once the DNA has been amplified, again electrophoresis or chromatography is used to size the amplified band.

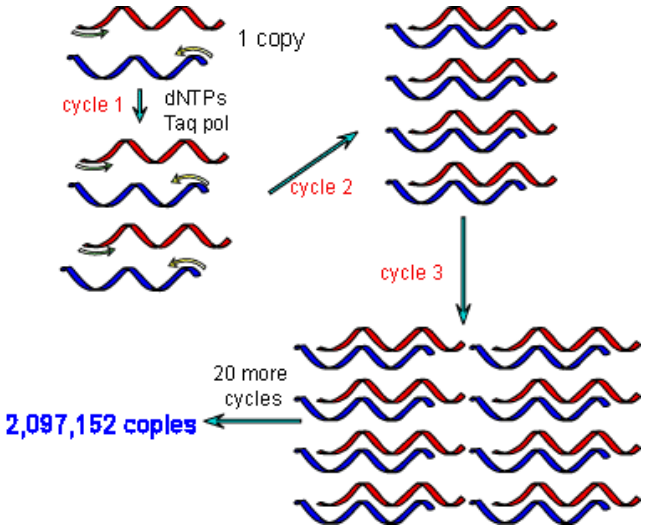

Figure-3: Diagram of PCR. In this process, the template DNA is denatured (upper left), then primers are annealed (gray) which act as start sites for DNA synthesis (upper right). Only 20 cycles are required to produce two million copies (Bioteach, 2006).

PCR can only efficiently amplify bands below about 2kb, so PCR is usually applied to STRs, not to the longer VNTRs. Although PCR is less accurate than RFLP analysis (Taq polymerase can make mistakes), it is used more frequently in practice. It takes much less time to complete – usually one day. The test can be performed with very small crime scene samples, which helps investigators who have little physical evidence. The DNA does not have to be recently collected; the PCR test can still be performed even years after the crime from very small amounts of DNA isolated from bone. However, PCR is very sensitive and prone to contamination. If we are amplifying a sample of DNA and there happens to be DNA present from another person, we would end up amplifying and subsequently analyzing the second persons' DNA as well, possibly ruining our results (The Gene School, 2010).

Both DNA tests produce a DNA fingerprint. There are three determinations one can make with a fingerprint – inclusions, exclusions or non-conclusive. If a DNA profile matches the

profile of another DNA sample, the results are considered an inclusion. The first source may have the same origin as the second sample. In the case of a crime for inclusive DNA, the suspect cannot be excluded from consideration. But there is still a small possibility of a false positive, and the DNAs came from different sources, so an inclusive result is viewed with caution. An exclusion is determined when the fingerprints do not match. For exclusions, we can confidently say that the individuals must be different because they differ at a location. Lastly, non-conclusive results may occur if the samples are contaminated, degraded, or of insufficient quantity. Degraded samples may not have the loci that we test for, and thus no useful bands will be produced (Meeker-O'Connell, 2004).

DNA Fingerprinting Applications

Since DNA fingerprinting can accurately determine whether two samples are from the same person, it has been used extensively in law enforcement. A DNA fingerprint can help incriminate a suspect if a sample from the crime scene matches the DNA from a suspect. The suspect would have to explain why his DNA was found there if he is indeed innocent.

DNA fingerprinting has helped solve crimes where there is no suspect, cold-cases. In many cases, such as rapes and murders, the criminal is gone by the time the police arrive. Luckily for us we are still able to collect DNA from the culprit in the form of hairs, skin, saliva etc. The FBI has developed a database of DNA fingerprints called CODIS that is constantly reviewing unsolved crimes as new DNA profiles are submitted. This means if the DNA fingerprint from an old unsolved crime matches the DNA from someone recently added to the database, that person is now a prime suspect for the old crime.

But DNA can also help set innocent people free. The same technology has been applied to cases where DNA evidence became available after a man has been sentenced to jail. In these cases, perhaps DNA testing was not available for the original trial, but when the suspect's DNA was compared against crime scene evidence it did not match, so the person is exonerated. In these cases, if even one loci does not match it must be enough to set the person free.

Paternity testing is now very commonplace. We use DNA fingerprinting to determine whether an alleged parent or child does indeed have that genetic relationship. Courts now routinely accept paternity test results as a valid (and mostly irrefutable) means of determining the identity of a child's father for the purpose of instituting orders for child support (Notes On Paternity Testing, 2010).

Identification of unknown remains has become easier with DNA profiling. Often bodies are found that are damaged beyond recognition – car crashes, burns, decomposition etc. In cases where not even dental records would be helpful, a DNA fingerprint can be compared to samples from families of missing persons to see if a match can be made. The military now requires a DNA sample to identify soldiers who die while on duty, superseding the dog-tag. In other cases, a fingerprint could help determine the person's sex or race which may help narrow the possible identities.

Archeologists have been able to successfully employ DNA fingerprinting to clarify history. For example Y-chromosome testing was used to determine whether Thomas Jefferson fathered children with one of his slaves. They have also tried to map the evolution of human populations, how they migrated and diversified into many races throughout history (Christianson, 2000).

We have even created DNA fingerprints from non-humans. In 2000, the viticulture community was shocked to find that sixteen of the most highly prized varieties of wine-making grapes were the product of mating between the classic Pinot and the undervalued Gouais grape. The Gouais was considered such an inferior specimen that there were attempts to ban its cultivation in France during the middle ages. In a different case, detectives in Phoenix Arizona were able to link a suspect to a murder victim by testing the DNA of a tree found at the crime scene, to pods found in the suspect's truck (Meeker-O'Connell, 2004).

Chapter-1 Conclusion

DNA fingerprinting has become invaluable as a tool for modern society. Its unique ability to identify the origins of DNA material has allowed us to better execute justice and gain valuable knowledge. Though there may be issues involved such as false-positives and statistically unlikely matches, the more we use and standardize the technology, the better we become at using DNA for the improvement of society.

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CHAPTER-2: DNA FORENSICS

Andrew Vickery

The purpose of this chapter is to illustrate the advancements in DNA forensics in the past ten years that increases the chances of a court allowing DNA evidence to be introduced. When performed properly, DNA fingerprinting is a powerful identification tool. But when proper controls are not utilized, or the DNA is contaminated or degraded, the evidence can be prevented from use in a courtroom. In response to early criticism, scientists have learned new ways for preventing DNA degradation or contamination, and for documenting evidence to prevent potential tampering. The following pages will demonstrate the importance of how DNA evidence is collected and maintained, and the importance of maintaining a proper evidence chain of custody.

The OJ Case and Forensics

The O.J. Simpson murder case (People v. Simpson), argued by some to be the "Trial of the Century", is an example of improper handling of DNA evidence (USA Today, 1996; Linder, 2000). Police scientist, Andrea Mazzola, who had collected blood samples from Simpson to compare with evidence obtained from the crime scene, was a beginning trainee and carried the vial of Simpson's blood in the pocket of her lab coat for almost an entire day before entering it as an exhibit. During the trial, the defense attorneys argued that "bungling" police technicians handled the blood samples with such a degree of incompetence, that accurate and reliable DNA results were almost impossible (Lerner and Wilmoth, 2006). As another example, the Los Angeles County District Attorney's Office and the Medical Examiner's Office could not explain

why 1.5 cc of blood was missing from the original 8 cc of blood taken from Simpson, supposedly due to questionable chain of custody; the defense argued that the missing 1.5 cc could have been used to spike crime scene evidence to help convict the defendant (Van Hollen, 2009). Moreover, evidence collected by Los Angeles Police criminologist Dennis Fung was deemed questionable when he admitted to "having missed a few drops of blood on a fence near the bodies", and he stated at trial that he "returned several weeks afterwards to collect them" (National Institutes of Justice, 1999). Fung admitted he did not use rubber gloves when collecting some of the evidence.

Simpson's verdict of "not guilty" at the criminal trial is questioned to this day. Some jurors interviewed have stated they believed Simpson "probably" did commit the murders, but police errors on evidence collected at the crime scene, caused "reasonable doubt" in their minds, and led to their verdict of not guilty (USA Today, 1996). Simpson was later found liable for the two deaths at his civil trial, where the evidence was based on the lesser standard of "preponderance of the evidence". Regardless of the outcome of the OJ criminal trial, it sent a powerful message to all of law enforcement to train DNA technicians to higher standards.

COLLECTION OF DNA EVIDENCE

At crime scenes, DNA can be found in a variety of tissues and secretions. And with the advent of PCR technology, DNA can be obtained from amazingly small samples. The most commonly collected DNA evidence includes:

1. Blood stains: found on anything, including clothing, weapons, objects, and fingernail scrapings;

2. Semen stains: found on clothing, bedding, swabs from victims or suspects (sexual assault kits), condoms, carpeting, vehicles, upholstery and other objects;

3. Saliva stains: from cigarette butts, swabs from victims, bite marks, stamps, envelopes, bottles, cans and clothing;

4. Vaginal secretions: found on clothing from suspects, external penile swabbings, condoms, fingers and objects;

5. Tissue (skin cells): found on fingernail scrapings, visible material from a vehicle or weapon, tape or ligatures, intimate objects, eyeglasses, earrings, clothing (wearer's), guns or knives (grips/handles);

6. Hair roots: found on head hairs from intimate objects, public hairs from clothing/intimate objects/public hair combings. There must be cellular material present in the hair for DNA analysis;

7. Perspiration: from hats, jackets, ski masks, bandannas, gloves, handled objects, weapons, eyeglasses, etc.

(Evidence Collection, 2007)

Less commonly, other sources of DNA evidence cannot be overlooked, such as urine, feces, vomit, food, fired casings, drug baggies, and fetal tissue. During evidence collection, the crime scene investigator must think of any evidence that might contain DNA, and take every precaution to prevent its contamination or degradation during its collection, submission, and storage. There are three basic techniques for the collection of stains or touched items: (1) Collect the entire stained item and place it in a paper or cardboard box (however, this does not include very large items, such as furniture or carpets); (2) for such items as cloth, carpeting, or bedding, cut out a piece of the item containing the stain; (3) for large non-cuttable items, swab the stain off the item using a minimum number of swabs to collect all the stain or at least one well-coated swab. When swabbing DNA evidence a proper technique that needs to be followed:

1. Use a sterile swab lightly moistened with water;

2. Swab the stain with the moistened swab, and follow-up with a dry swab (especially on hard surface items such as weapons, wood, etc.) to collect any remaining cells. Air dry both swabs and package together;

3. Use 1 or 2 well-coated swabs for body fluid stains;

4. Use only 1 or 2 swab sets (wet swab followed by dry swab) for touched items;

5. for food, vomit, fecal material, gum, and any biodegradable material:
Freeze the item before swabbing; Swab bitten portion of food; Swab exterior of vomit and fecal material so as to only collect surface cells.

(Van Hollen, 2009)

Two procedures are commonly used for taking DNA samples from human subjects: 1) a buccal swab taken from the cheek (the preferred type), and 2) liquid blood drawn into an EDTA containing tube (purple-top). The EDTA serves to prevent blood coagulation and DNA degradation. All layers of packaging, including the swab box or blood tube, should be labeled with the name of the individual and the individual's date of birth. When buccal swabs are used, a traditional fingerprint from the individual swabbed may be placed on the swab label for additional identification.

The use of *elimination samples* are extremely important in all DNA cases. Elimination samples are those taken from individuals known *not* to be the perpetrator. Examples of elimination samples include: prior consensual sex partners in sexual assault cases (up to 96 hours prior to the assault), owners of homes or vehicles with legitimate access to collected items (such as the owner of a house burglarized or the owner of a stolen car). Elimination samples are only used by the laboratory for elimination purposes, and are not entered into any database. The samples are returned to the submitting agency when the crime scene analysis is completed.

The use of the chemical luminol at a crime scene where a perpetrator has “cleaned” the scene leaving no visible evidence, allows the detection of very small particles of biological fluids, especially blood. Luminol enables the detection of these otherwise invisible particles, due

to a light-producing chemical reaction between the blood and luminol. Light is emitted since the reactants contain more energy than the product of the reaction, causing the extra energy to be released as light photons. Once the luminol is sprayed on the object, on all other forms of light are turned off, any area containing even the smallest amount of blood will show up as blue. At this point, the forensic investigator photographs or videotapes the crime scene, recording any potential patterns that may exist. However, it is important to note that if the entire sample is treated with luminol, it is no longer able to be used for DNA evidence since luminal destroys DNA upon contact. **Figure-1** shows the use of luminal on blood, producing a blue glow (Harris, 2005).

Figure-1: A Simulation of Luminol at Work. Before spraying luminol (left photograph), there is no visible sign of blood. After spraying luminol (right photograph), the latent blood traces react with luminol to emit a blue glow. (Harris, 2005)

An important part of a crime scene investigation is blood stain pattern analysis. The measurement and documentation of drop size, shape, and pattern (**Figure-2**) can provide the direction and angles, originating point, and the number of blows in a stabbing or beating crime. The figure illustrates how the appearance of a blood drop changes according to the angle it

impacts a surface. A blood drop falling straight downward at a 90º angle to the surface (diagram right side) will appear round. When the angle the blood hits the surface becomes more acute (diagram left side) the drop becomes longer.

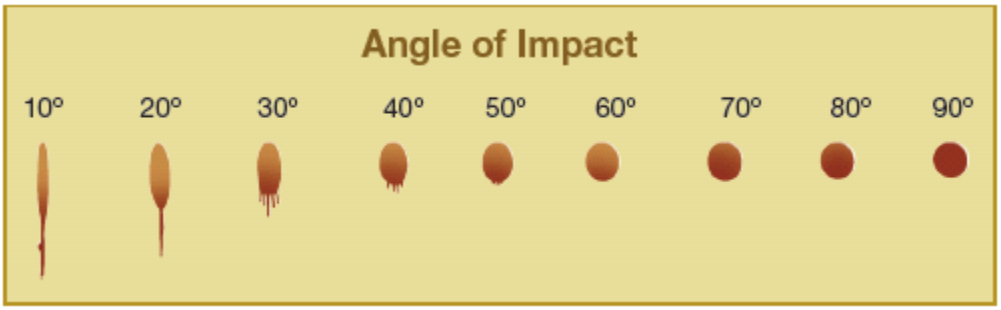

Figure-2: Appearance of Blood Drops Hitting Surface at Various Angles. A drop hitting a surface at a 90° angle (right side) will appear round, while a drop hitting at a 10° angle (left side) will be more elongated. (Van Hollen, 2009)

When collecting blood stains, the crime scene investigator needs to document: the physical state (whether moist, fluid or dry), the amount (a few drops, small pool, etc.), the shape of the blood stain (round, smeared), the exact location of the blood related to fixed objects, the pattern of the stains (whether they are together in one spot, or if there is a trail of blood), the temperature and humidity at the time, the date and time of observation, and any scaled and unscaled photographs of the stains (Van Hollen, 2009).

Once the sample has been obtained, it is extremely important for the crime scene investigator to document "chain of custody". For any evidence to be used in court it must be validated and secured to assure it has not been contaminated, is relevant to the investigation, and will not be tampered with. To help ensure chain of custody, the person collecting evidence at the crime scene signs his/her initials and date, either on the item or on its packaging. The receiving individual at the laboratory signs the evidence package and dates it. Everyone who handles the evidence signs and dates it until completion of the analysis. Once the analysis is complete, the

evidence is turned over to the police for storage until presented in court. The police officer receiving the evidence signs for it, and stores it in a secure area. At court the prosecuting attorney takes over custody of the evidence and signs indicating such. The proper handling of evidence chain of custody allows the evidence to be allowed in court. If the chain of custody is broken, questions arise as to the validity of such evidence, causing crucial evidence to be disallowed (Lerner and Wilmoth, 2006).

STORAGE OF DNA EVIDENCE

Once the DNA evidence has been collected, it is vital that evidence be packaged properly to avoid contamination, degradation, or tampering. All items should be dry and packaged in paper, never plastic, since plastic promotes the growth of mold and bacteria which destroys the DNA (Evidence Submission, 2006). Each item needs to be packaged separately, including swabs (all swabs collected from the same stain should be packaged together), then sealed and marked. The marking is done not only to identify the sample but to maintain a "chain of custody". The collector's signature is placed on a seal to prevent anyone else from opening the sample without detection.

It is very important that the items be sealed in packages appropriately sized for the evidence. When the evidence is at the laboratory, the package is opened and resealed which requires there to be enough room to remove the evidence, return it after analysis, and reseal the package. All layers of packaging should be labeled, for example one envelope inside another. Knives and other sharp items need to be protected not to allow them to penetrate the packaging, requiring them to be tied down in a heavy cardboard box. If blood flakes are present on the evidence, any gaps in the box must be covered with tape to prevent contaminating the outside

package. Weapons must have the handles or touched areas wrapped separately from any body fluid stains on the weapons to prevent cross-contamination.

The proper storage temperature of DNA evidence at the laboratory is crucial to the investigation. If the DNA is to be stored for a relatively short time, room temperature is acceptable. Liquid samples, such as blood or urine, need to be kept refrigerated. Food, fecal bacteria, and mold should be kept in a cool, dry area. Any biological evidence needs to be transported to the laboratory as soon as possible to avoid contamination.

After DNA analysis, the long-term storage of evidence must be according to state law. DNA return packets need to be frozen in a "frost-free freezer" and sealed in plastic. Any liquid samples, such as blood and urine, need to be refrigerated or frozen. All food, fecal material, fetal tissue and vomit should be frozen to prevent mold and bacteria from growing (National Institute of Justice, 1999; Van Hollen, 2009).

Chapter-2 Conclusion

Advancements in DNA technology allow cases to be solved that were previously unsolvable. Evidence not seen by the naked eye can be the key to solving a crime. The use of PCR allows much smaller DNA samples to be tested, and even allows the use of partially degraded DNA. New advances in DNA collection and storage help prevent DNA contamination and degradation. Standardized procedures mandating the documentation of evidence "chain of custody" help prevent evidence tampering. All of these advances help make DNA evidence more acceptable in courts, and hopefully will help society convict the guilty while exonerating the innocent.

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CHAPTER-3: LANDMARK DNA COURTCASES

Andrew Vickery

The introduction of any type of complex evidence in the court room is an interesting problem in the interaction of society and technology. The technology may be new and unproven, or it may be overly complex to be understood by jurors. Both of these problems occurred with the advent of DNA fingerprinting. The purpose of this chapter is to discuss the introduction of DNA evidence into the court room as an example of the interaction of technology with society.

Frye v. U.S., 1923

On August 21, 1921, James Alphonzo Frye was arrested after committing armed robbery, for the murder of Dr. Robert W. Brown. The robbery was alleged to have happened on November 25th 1920. Frye confessed to both the robbery and the murder of Dr. Brown. Two years later in 1923, Frye appealed his conviction for second degree murder, citing that the original Court refused to let him introduce evidence about his truthfulness through a "systolic blood pressure deception test," a crude precursor to what is now popularly known as a lie detector, or polygraph test, along with the introduction of an expert witness to testify about the deception test. Frye had passed this deception test, and wanted the data entered as evidence (Frye v. United States, 1923; Frye v. US – Significance, 2010). In a unanimous decision, the three-judge Court of Appeals of the District of Columbia ruled for the United States (against Frye) in a short opinion that became one of the most famous opinions ever written by a federal appeals court:

> In the court's opinion, the systolic blood pressure deception test had not gained enough "standing and scientific recognition among physiological and psychological authorities" to justify its admission as evidence in courts of law. (Frye v. US - Impact, 2010)

Thus, the Court of Appeals approved the exclusion of the “deception test” because it had not gained a *general acceptance* in the scientific community, and Frye's original conviction was affirmed. In the court opinion, written by Justice Van Orsdel, the court described how the machine operated and how, when attached to a subject, it supposedly could detect whether a subject was being deceptive. Frye argued that systolic blood pressure rose in a predictable curve when a subject was being deceptive and afraid that the falsehood could be detected (Frye v. US, Significance, 2010). The court characterized the information offered by Frye as only a "theory", and since there were no prior similar cases to use as guidance, the court was left to make up a rule on the admissibility in court of deception tests. Frye insisted that the deception test could be explained by a witness who was an expert in the field, but the court rejected this. The Frye case set a standard for accepting expert testimony in court, requiring a general acceptance in the scientific community for new technology. (Frye v. US - Impact, 2010)

The *Frye Standard* for admitting evidence remained the gold standard for about 52 years, until 1975 with the introduction of the Federal Rules of Evidence. The standard eventually proved too difficult for courts to manage as the scientific community expanded and progressed, so more flexible standards were introduced. Lie detector tests remained inadmissible as evidence in most courts for many years; but in the 1970s and 1980s, lie detection gained some respect in the scientific community and some courts started admitting the evidence under certain limited situations in both criminal and civil trials. However, most states still prohibit all forms of polygraph evidence.(Frye v. US - Impact, 2010)

Federal Rules of Evidence 702, 1975

In 1975, due to Frye's poor wording and stringent *general acceptance* limitations on the admissibility of new technologies and techniques, Congress enacted the Federal Rules of Evidence 702, a more lenient alternative to the Frye Standard. Rule 702 promoted the *reliability and relevancy* of new technologies, as opposed to general acceptance. Rule 702 provided:

> "[A] witness qualified as an expert . . . may testify . . . in the form of an opinion or otherwise if:
> 1. testimony is based upon sufficient facts or data,
> 2. testimony is the product of reliable principles and methods, and
> 3. witness has applied the principles and methods reliably to the facts of the case." (Bucklin.org)

In 2000, Rule 702 was amended in response to Daubert v. Merrell Dow Pharmaceuticals (1993), and to the many cases applying a new *Daubert Standard*. In Daubert, the Court charged trial judges with the responsibility of acting as gatekeepers to exclude unreliable expert testimony, and this gatekeeper function applied to all expert testimony, not just testimony based in science. As such, the 2000 Rule 702 amendment affirmed the trial court's role as gatekeeper, and provided some general standards to assess the *reliability* and *helpfulness* of offered expert testimony. The specific factors demanded by Daubert were:

> 1. whether the expert's technique or theory can be or has been tested – can the expert's theory be challenged in an objective sense, or is it simply a subjective approach that cannot be reasonably assessed for reliability.
> 2. has the technique or theory been subject to peer review and publication.
> 3. the known or potential rate of error of the technique or theory when applied.
> 4. the existence and maintenance of standards and controls.
> 5. has the technique or theory been generally accepted in the scientific community.
> (Rule 702, Cornell University)

After the revision, Rule 702 required any expert, including non scientists, should receive the same degree of scrutiny for reliability as an opinion from a scientific expert. The Rules Committee also identified five other factors to be considered:

1) whether the testimony concerns matters growing naturally and directly out of research the expert has conducted independent of the litigation;
2) whether the expert has unjustifiably extrapolated from an accepted premise to an unfounded conclusion;
3) whether the expert has adequately accounted for obvious alternative explanations;
4) whether the expert is being as careful as he would be in his regular professional work outside his paid litigation consulting; and
5) whether the field of expertise claimed by the expert is known to reach reliable results for the type of opinion the expert would give. (Bucklin.org)

Colin Pitchfork, 1987

On the morning of November 22, 1983, 15-year-old Lynda Mann was found raped, and strangled, on a deserted footpath known to locals in England as the Black Pad. Forensic evidence using a semen sample taken from her body showed that the perpetrator was a person with type A blood, and an enzyme profile which only 10 percent of males match. On July 31, 1986, another 15-year-old girl's body, that of Dawn Ashworth, was found in a wooded area near a footpath called Ten Pound Lane. She had been beaten, savagely raped, and strangled to death. The *modus operandi* matched that of the first attack, and semen samples revealed the same type-A blood type. The prime suspect was a local 17-year-old youth, Richard Buckland, who revealed knowledge about Ashworth's body, and admitted the crime under questioning, but denied the first murder. Alec Jeffreys, of the University of Leicester, had recently developed DNA profiling along with Peter Gill and Dave Werrett of the Forensic Science Service (FSS), and detailed the technique in a 1985 paper (Jeffreys et al., 1985). Using this technique, Jeffreys compared the semen samples from both murders against a blood sample from Buckland, and the results

conclusively proved that both girls were killed by the same man, but not the suspect (Lambert, 2009).

On September 19th, 1987, Colin Pitchfork was arrested at his home in Haybarn Close in the neighboring village of Littlethorpe for the rape and murder of the two teenage girls, after a man named Ian Kelly was heard bragging that he had obtained £200 for giving a sample while masquerading as his friend, Colin Pitchfork, a local baker. Pitchfork's DNA profile was found to match that of the killer. He was sentenced to life inprisonment on January 22, 1988, after admitting to both murders (Explore Forensics, 2010).

The Pitchfork case was the first murder conviction based on DNA profiling evidence (Colin Pitchfork), as well as the first exoneration based on DNA (for Richard Buckland). (Forensic Cases: Colin Pitchfork, Explore Forensics) Pitchfork appealed his sentence of 30 years on May 14, 2009. He won his appeal and had his sentence reduced to 28 years and is eligible to be released in 2016. It is noted, however, that the Lord Chief Justice indicated Pitchfork cannot be released "unless and until the safety of the public can be assured" (Kennedy, 2009).

Post-conviction DNA testing has allowed at least 232 American convicts to prove their innocence and be released from prison. In 2000, the Governor of Illinois declared a moratorium on executions due to the fact that many Illinois death row inmates were proven innocent as a result of DNA testing. The Federal government has laws that give convicts some access to DNA testing, as well as all 50 states except for Alaska, Massachusetts, and Oklahoma – who oppose post-conviction DNA testing due to the cost and additional litigation it might cause (Robinson, 2009).

People v. Castro, 1989

On February 5, 1987, Vilma Ponce and her two-year-old daughter were stabbed to death in the Bronx, New York. Castro was a handyman in the neighborhood where Ponce lived, and when police questioned him they observed a bloodstain on Castro's watch. Blood samples of the victims and blood scraped from Castro's watch were sent to Lifecodes for DNA fingerprinting analysis. The results indicated a match between the samples. At the time there was no mention of any difficulties or ambiguities noted during the processing of the evidence (Patton, 1990).

In the Spring of 1989 a "Frye-Middleton" hearing was held in the Superior Court of Bronx County, New York, to determine the admissablility of the Castro DNA analysis. On August 14, 1989 the court ruled that "DNA forensic identification tests" were acceptable for both inculpatory and exculpatory evidence. However, the Court ruled that in the Castro case, the laboratory, Lifecodes, did not apply approved procedures, so the DNA "evidence of guilt" was not admitted. The decision was not appealed as Castro pled guilty to the murders in late 1989 (Patton, 1990; Fiatal, 1990).

As a result of *Castro*, the Frye test was revised to establish a *Three Prong Test* for the allowance of DNA fingerprinting:

> ***Prong I****: "Is there a theory which is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results?"*
>
> ***Prong II****: "Are there techniques or experiments that currently exist that are capable of producing reliable results in DNA identification and which are generally accepted in the scientific community?"*
>
> ***Prong III****: "Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case?"* (Patton, 1990)

The court ruled that Lifecodes did not follow accepted scientific procedures in its analysis of DNA in the *Castro* case because it failed to perform "certain experiments, techniques, and controls necessary to produce reliable results", so it was suggested that all cases in which there is DNA fingerprinting evidence should include a *Prong III Hearing* to insure techniques used in the analysis meet the Frye standard (Patton, 1990).

The second main outcome of the Castro case was the recommendation for increased standards in DNA testing technology. In response, the FBI created the Technical Working Group on DNA Analysis Methods (TWGDAM) that eventually helped to standardize protocols for DNA testing with appropriate controls (Tilstone, 2006).

U.S. v. Matthew Two Bulls, 1990

In 1990, Matthew Sylvester Two Bulls was charged with aggravated sexual abuse, and sexual abuse of a minor, arising out of the rape of a fourteen-year-old girl on the Pine Ridge Indian Reservation in South Dakota. The police seized the underwear the girl was wearing before and after the incident. The FBI Laboratory isolated DNA from the semen stain on her underwear. The profile matched that of the DNA from Two Bulls' blood, so the government concluded that there was a very high probability that the semen on the underwear came from Two Bulls. Before trial, Two Bulls made a motion for a suppression hearing challenging the admissibility of his DNA evidence. At the pre-trial hearing, after hearing only the testimony of the government's first witness, the district judge ruled that it had been sufficiently established that DNA evidence was generally accepted by the scientific community, so the Two Bulls DNA evidence could be presented to the jury, resulting in a conviction.
(US v. Two Bulls- Court of Appeals, 1990)

Two Bulls insisted that the trial court erred because it applied *Federal Rule of Evidence 702* in determining the admissibility of the DNA evidence instead of using the more rigorous *Frye Standard*. He argued the district court violated his due process because the pre-trial suppression hearing was incomplete. Two Bulls also asserted that a three step test should have been used to determine the admissibility of his DNA evidence, similar to a *Castro Prong III* test, where the three step analysis would aid in evaluating and resolving the admissibility issue. In *Castro*, the court focused mostly on resolving the third prong of whether the laboratory used accepted scientific techniques for performing the analysis. The *Castro* court observed that "[p]erhaps the most important flaw in the *Frye* test is that by focusing attention on the general acceptance issue, the test obscures critical problems in the use of a particular technique." The *Two Bulls* appellate court ruled that *Rule 702* was too lenient for DNA evidence, and a more rigorous standard should be followed. Two Bulls' original conviction was vacated, and the conditional plea set aside to remand the case to a trial court where the admissibility of the DNA evidence was examined by a new 5 criteria that merged the *Castro Prong III* test with the *Frye Standard*:

> 1. whether DNA evidence is generally accepted by the scientific community.
> 2. whether the testing procedures used in this case are generally accepted as reliable if performed properly.
> 3. whether the test was performed properly in this case.
> 4. whether the evidence is more prejudicial than probative in this case.
> 5. whether the statistics used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial under Rule 403.
> (US v. Two Bulls- Court of Appeals, 1990)

At the trial court, using the new *Two Bulls 5 Prong Test*, the DNA evidence was allowed in court, and Two Bulls was convicted (US v. Two Bulls- Court of Appeals, 1990).

Daubert v Merrell Dow Pharmaceuticals, 1989; 1991; and 1993

Jason Daubert's parents, William and Joyce Daubert, and Eric Schuller Jr.'s father Eric Schuller, sued Merrell Dow Pharmaceuticals claiming that their son's serious birth defects were caused by the mothers' prenatal ingestion of a prescription drug called Bendectin which was marketed by Dow Pharmeucaticals. The case was moved from California to a Federal District Court where Dow provided expert testimony concluding that "upon reviewing the extensive published scientific literature on the subject, maternal use of Bendectin has not been shown to be a risk factor for human birth defects." (Daubert, Cornell University)

The plaintiffs responded with experts of their own, who based their findings that Bendectin can cause birth defects on animal studies, chemical structure analyses, and unpublished "reanalysis" of previously published human statistical studies. The Court ruled that the plaintiff's experts did not meet the Frye "general acceptance" standard for admission of expert testimony, stating that scientific evidence is only admissible if the principle on which it is based is "sufficiently established to have general acceptance in the field to which it belongs." (Daubert, Cornell University)

The case was appealed to the Ninth Circuit of the U.S. Court of Appeals. The Ninth Circuit agreed with the district court's ruling citing Frye v US that "expert opinion based on a scientific technique is inadmissible unless the technique is 'generally accepted' as reliable in the relevant scientific community" (FindLaw, 1993).

The plaintiffs appealed to the U.S. Supreme Court stating that the *Federal Rules of Evidence* superseded Frye's "general acceptance" test. The Supreme Court eventually ruled that the *Rules of Evidence* were designed to expand the range of admissible evidence, and stated that the trial judge was to ensure that expert testimony was relevant and reliable. The Supreme Court

ruled in favor of the plaintiffs, and reversed the Ninth Circuit's exclusion of the plaintiff's expert testimony. The decision became known as the *Daubert Standard of Evidence Admissibility*, and sets forth the five criteria:

1) Has the theory/technique been tested?
2) Has the theory/technique been subjected to peer review and publication?
3) Does the theory/technique have a known /potential rate of error?
4) Does the theory/technique have standards for controlling the operation?
5) Has the theory/technique been accepted in the scientific community and to what degree? (Daubert, Cornell University)

The Ninth Circuit reconsidered the expert testimony of the plaintiffs using the new *Daubert Standard* and found that the testimony was inadmissible. Thus, the Ninth Circuit upheld the district court's initial ruling to exclude the plaintiffs experts' testimony. The *Daubert Standard* has generally been successful in excluding "junk science", as well as new or experimental techniques and research from being admitted as evidence (Daubert, Cornell University).

People v. Paul Eugene Robinson, 1994, 2000, 2003

On August 25, 1994, a twenty four year old woman in California was awoken in her bedroom by a stranger who proceeded to rape her twice. A vaginal swab was positive for semen. In August of 2000, just prior to the expiration of the case by a six year Satute of Limitations, a DNA profile was obtained from the vaginal semen for the unknown defendant. The Statute of Limitations was set to expire on August 25, 2000 for the 1994 rape; however, the Sacramento County District Attorney filed a felony complaint against "John Doe, unknown male", in which the defendant was described by a 13-locus DNA profile developed from semen from the victim

of the 1994 rape. On August 21, 2000, an arrest warrant (John Doe DNA Warrant) was issued incorporating the DNA profile.

A search of the Department of Justice (DOJ) Convicted Offender Databank was conducted to determine whether the DNA profile of the 1994 assailant matched the DNA profile of any convicted offender in the databank. Paul Eugene Robinson's name was obtained from a match of the 13-locus DNA profile of the perpetrator. On September 15, 2000, Robinson was arrested for the 1994 rape, and subsequently convicted on five counts of sexual assault and sentenced to the maximum term of 65 years in state prison solely on the basis of his DNA, with no corroborating witnesses (People v. Robinson, 2007; Scully, 2003).

Robinson appealed his conviction, arguing that his prosecution was not based on the issuance of the arrest warrant because the warrant did not satisfy the particularity requirement of section 804, subdivision (d). The Court ruled (1) that the DNA profile of the perpetrator of a sexual offense incorporated into an arrest warrant provides particularity of identification of an offender required by section 804 (d); and (2) the Statute of Limitation for a sexual offense is satisfied when the prosecution is commenced within the period of limitations by filing of an arrest warrant predicated upon identification of the perpetrator by a DNA profile (Pen. Code, §804 (d) 1. (People v. Robinson, 2007)

Robinson's conviction was the first conviction in the State of California based upon filing of a "John Doe" warrant. On January 25, 2010, the California Supreme Court ruled 5-2 that prosecutors can file arrest warrants based on DNA to "get around" legal deadlines. This ruling upheld Robinson's conviction. (Dolan, 2010)

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Chapter-4: DNA Database Ethics

Harry Moreno

The Merriam-Webster dictionary defines ethics as "a set of moral issues or aspects (as rightness)". So when we refer to DNA database ethics, we are talking about a set of moral issues pertaining to the collection of DNA from people and storing their DNA profiles in a database. The right to privacy, an interpretation of the Fourth Amendment "protection from search and seizure", is frequently brought up in DNA discussions and who should provide their DNA to databases. In the US, these issues are decided by individual state laws, and every state has debated this issue extensively. Should we collect DNA from everyone, or only from certain people, or not at all?

The CODIS Database

After the original development of DNA fingerprinting technology by Alex Jeffreys in the mid-1980's (Jeffreys et al., 1985), interest in DNA as a tool for justice significantly increased in the late 1980's, following a series of landmark court cases that showed the new technology to be accepted in the scientific community and reliable, so this technology could be used as evidence in courts. In 1990, its increased use lead to the creation of the FBI's Combined DNA Index System (CODIS). CODIS started in 1990 with 12 states participating in a pilot program (Adams, 2002). Currently all 50 states participate in CODIS, although the DNA collection policy varies by state. The term CODIS is actually used not only to describe the database, but also the software used to scan the database, and its various indices at the national, state, and local levels.

CODIS currently has over eight million offender profiles, making it the largest DNA database in the world (FBI.gov, 2010).

The underlying motivation of CODIS, and where it truly shines, is the 'cold hit'. CODIS is most useful in cases where there is no suspect based on traditional evidence. So the DNA profile from the perpetrator at a crimescene is compared to a database of previous offenders (the offender index) or to other crime scene profiles (the evidence index) to see if a cold hit takes place. DNA is left at a crime scene in the form of blood, saliva, hair, or any other source of human cells. The investigators can collect the evidence, analyze the DNA by RFLP or STR (as discussed in Chapter-1), then submit the profile into the database. If the DNA genotype profile matches any other cases, the cases are linked, and the respective case handlers are informed that a new development has occurred. This new information can link crimes that would otherwise not be correlated. If the DNA matches a known person already in the database, then it is very likely that the person was present at both crime scenes, and is labeled as a suspect. All new cases are routinely checked against CODIS. If either type of match occurs it is called a 'hit'.

Databases and Match Probabilities

When we analyze someone's DNA, we don't actually sequence it from beginning to end (that has only happened a few times in history due to the time and labor involved). Instead, we analyze 13 core loci (locations) along the DNA that molecular biologists have identified over the years as being different between individuals, and which can reliably be tested. The more loci we test, the better we can trust the results. The 13 core loci tested in the U.S. (other countries may test other loci) were specifically selected because they are not linked to any genetic code or medical condition (DNA Consultants, 2010).

To determine match probability, it is important to understand the frequency of each type of locus (allele frequency) relative to the general population. Since we do not have everyone's DNA profile, to determine allele frequency we rely on CODIS itself and its eight million entries. So CODIS is not just important to find cold hits, it is also important to help define allele frequencies. It is also important to know the strength of these statistics. A frequency based on 100 samples is less strong than one based on 100,000 samples. Thus, as CODIS grows we can expect the results to be more statistically accurate.

DNA matching does not give us a strictly yes or no answer; it provides an approximate level of certainty. Each locus has a specific frequency, how often it appears in the general population. For example, let's say that 90% of the population exhibits marker-10 at locus-1, and 50% marker-11 at locus-2. For an individual showing markers 10 and 11, we multiply these frequencies together to say that 45% of the population will exhibit these same markers. Note that the final figure is smaller than the frequency which we observe for each individual locus. Since we examine 13 different loci for CODIS, and each locus has a specific frequency, we expect the final figure to be a very small number (DNA profile probability, 2010). When all 13 loci are analyzed, scientists believe the likelihood of two individuals (excluding identical twins) having the same profile is about one in a quintillion (1 followed by 18 zeros). For four loci, the probability is only 1 in 7,000 (DNA Profile Probability, 2010). In courts, the value can vary if some loci can not be analyzed due to partial sample degradation. So jurors should understand that the probability number can actually vary from case to case.

A challenge to this line of thought is the possibility of two persons producing the same results. In 1999 in Britain, a man's DNA profile matched burglary evidence at six loci, and he was arrested and incarcerated, but he later provided a strong credible alibi. Only when a retest using additional markers (ten) was performed did they find he did not match at the other loci.

This has been coined as the one in 37 million mistake (Moenssens, 2000). So we must analyze as many of the 13 core loci as possible to prevent such mistakes from occurring. It's a concern we must address as CODIS increases in size. The case reminds us that DNA technology is growing and changing, and is just another piece of evidence that should be weighed in court against other evidence, statistically powerful as it maybe.

Statistics can be manipulated to mean whatever you want them to be, these match percentages are no exception. Often the prosecution will phrase it as follows, "the chance is one in a billion that someone (anyone) other than the suspect left the stain". If fewer than 13 loci were analyzed, it is important to be truthful about a higher likelihood of a false match. It's the responsibility of the court to make sure everyone understands what these numbers mean.

Whose DNA Should Be Entered?

Who is required to contribute their DNA profile to CODIS varies by state. Generally speaking, all sexual offenders are required to submit their DNA to CODIS (State Laws on DNA Data Banks, 2010). Forty states currently require the collection of samples from all *convicted* felons, at least 38 require collection from convicts of certain qualifying misdemeanors, eleven allow from those *arrested* for specific crimes, and one state permits collection from individuals detained as suspects. Juvenile criminals are also included depending on state law. Massachusetts collects information from all sex offenders, all felons, and all juveniles that would have gone to jail had they not have been minors (Massachusetts General Laws, 2003).

Note that whose DNA profiles are required varies from *convicted* felons to some *arrestees*. And some states have even considered (but not passed) laws requiring *everyone* when born to provide a cheek swab for DNA. From purely a crimesolving point of view, the

"everyone" category would help, but you pick up privacy issues in this case, as these individuals have not committed a crime. So is the government allowed to catalog your DNA? And if so, under what circumstances?

Databases and Privacy Rights

There is no privacy law per-se in the U.S. Constitution or its amendments. The Fourteenth Amendment (Amendment XIV) to the United States Constitution, adopted on July 9, 1868, in its Due Process Clause prohibits state and local governments from depriving persons (individual or corporate) of life, liberty, or property without certain steps being taken (Wikipedia, 2010). And the Fourth Amendment (Amendment IV) to the United States Constitution is a part of the Bill of Rights which guards against unreasonable searches and seizures, and specifically requires search and arrest warrants by probable cause. But the amendments do not directly address privacy rights. However, the Supreme Court has found that other guarantees have "penumbras" that implicitly grant a right to privacy against government intrusion. The Supreme Court has also determined that offenders have a "diminished expectation of privacy" by virtue of their status as offenders (Compulsory DNA Collection, 2010), and that in those cases, law enforcement's interest in preventing future crimes outweighs an individual's right to privacy. Therefore, if you are a criminal the government has the right to collect your DNA.

There are two reasons for this diminished expectation of privacy. The first is straightforward, when you commit a crime the government has the right to intervene and put you in jail to serve time for that crime for justice to be exercised and to protect society. The second reason is to prevent future crimes. Being able to collect DNA from a person is a unique ability that can prevent a future crime. The government has the right to inconvenience a criminal

because convicted criminals are statistically more likely to commit a crime again. Why they are more likely to commit another crime is beyond the scope of this paper. Similarly, once a criminal has paid his debt to society and is free, CODIS still keeps his profile stored. It's the unique abilities of CODIS for which we have allowed a lowering of privacy.

Privacy is also a concern to non-criminals. So-called "DNA dragnets" occur when police seek samples from many individuals at a time, only one of which may have committed a crime, but they may feel stigmatized or under increased pressure if they refuse to provide a sample. There are also issues with "abandoned DNA" (DNA collected without a suspect's knowledge from discarded trash), where courts have determined that there is no "reasonable expectation of privacy" as the trash was discarded in a public place. Investigators have for example, followed suspects and collected their DNA without their consent from trash, then matched the DNA to the case for which they were first a suspect, and then they have cause to arrest him.

These practices however challenge the concept of being innocent until proven guilty. Privacy advocates argue that many times DNA collection occurs before the person is found guilty. Therefore, the premise of "diminished expectation of privacy" for a proven criminal is not applicable because the person is not yet proven to be a criminal. Effectively they feel like we are being treated guilty until proven innocent (ACLU, 2004).

Expunging DNA records often does not occur, or is very difficult when DNA is wrongly collected. The burden is placed upon the individual to prove that you were unreasonably tested, innocent, and then petition for the record to be expunged. "They must petition a judge who has discretion to deny their request, and is not even permitted to grant the request if the prosecuting attorney objects. Once denied, individuals are left with no right to appeal" (ACLU, 2004). The expunge laws and procedures vary by state.

Databases and Medical Information

But privacy rights are not the only database concerns reaching the headlines. We are always hearing about sensational stories of how health insurance companies and employers are going to gain medical information from databases, and use it to charge us more for medical insurance. In this case, it is very important to remember that CODIS only records information on the allele types at the 13 core loci. These loci have been very carefully chosen to not contain any known medical information, they contain only identifying information. So at this time, CODIS contains no medical information whatsoever. Scientists have linked certain gene sequences to Tay Sach's Disease, Cystic Fibrosis, Alzheimer's Disease, and Schizophrenia (NIH.Gov, 2008), it is not in CODIS's interest to record this data, as it would make CODIS's goals harder to achieve with privacy advocates.

You can not get more information out of CODIS than what is put in. In order to gain the medical information desired by companies, they would have to perform a more thorough test on the original stored DNA sample. This is theoretically possible as many labs store the samples long term. State laws are unclear or silent on the issue of what to do with the original sample after analyzing it. Only one state, Wisconsin, requires the destruction of offender specimens after profiling. So this matter must be addressed if privacy advocates are to be satiated. The author of this chapter agrees with the Wisconsin law requiring the destruction of DNA samples after obtaining CODIS information.

However, some labs justify saving the DNA samples because future uses may arise if someone needs to analyze more loci, or if the original results are questioned, if so the lab could

simply retest the sample. In Massachusetts, we do not dispose of stored DNA evidence. According to Massachusetts regulations 515 CMR 1.05(4):

> "DNA samples on FTA Blood Collection Paper, DNA Database Collection Cards, and DNA Database Identification Cards shall be stored indefinitely in a secure storage area unless otherwise required, as specified in M.G.L. c. 22E, section 15." (CMR, 2010)

But it is also possible for a Massachusetts resident to get the record expunged: upon reading M.G.L. 22E section 15:

> "Any person whose DNA record has been included in the state DNA database may apply to the superior court to have such record expunged on the grounds that the conviction or judicial determination that resulted in the inclusion of the person's DNA record in the state DNA database has been reversed and the case dismissed; provided, however, that one year shall have elapsed from the date the judgment reversing or dismissing the conviction became final or such person shall have obtained, in writing, authorization from the district attorney that no further prosecution is contemplated under the original offense for which such person was convicted or for which the original judicial determination was entered." (Massachusetts General Laws, 2010)

But when the Massachusetts law refers to record expunging, it does not mention the original DNA sample. It's not unreasonable that the state police would rather err on the side of sample preservation rather than err destroying the sample since the law is ambiguous.

Chapter-4 Conclusion

The author of this chapter believes that original DNA samples should be destroyed once a successful *reliable* CODIS identification has been obtained. If this is not done, it makes CODIS's forensic goals more difficult to achieve every time privacy advocates bring up these issues. Changing this policy to mandate sample destruction would help the public accept the benefits of DNA collection for identification purposes, without fear of exposing any medical

information. We should destroy the samples to protect our privacy while still reaping the benefits of CODIS.

With respect to *which* crimes mandate DNA collection, the author of this chapter agrees with collecting from *convicted* felons, but does not agree with some states like Virginia who want to collect DNA each time someone is detained. If DNA is collected from a suspect, the sample should immediately be destroyed if the person is later found innocent or after CODIS information is obtained.

With respect to privacy rights and medical information, the CODIS profile does not contain anything about genetics or medical predispositions. The CODIS identification loci have been very carefully selected to avoid this problem. Therefore, so long as the original DNA sample is destroyed, there should not be any fear that someone will hack into CODIS to retrieve medical information and use it against you.

With respect to whether *innocent* individuals should volunteer their DNA to increase the size of CODIS to provide even more accurate allele information, I believe this is no longer as much an issue as in the early days of DNA fingerprint analysis. CODIS has become so large that the allele frequencies are now far more accurate than they used to be, and in any case, CODIS will only continue to get larger each year.

CODIS is fundamental to the modern court system. It makes use of a very unique identifying technology, DNA, which helps us identify suspects and release the innocent. Although there are privacy concerns that will continue to be brought up, these can be minimized by destruction of the DNA sample after obtaining CODIS information. Currently, only the state of Wisconsin requires this, so we support all states passing similar legislation.

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PROJECT CONCLUSIONS

There are two main ways of obtaining a DNA fingerprint, RFLP and PCR. The RFLP assay was developed first, and is more accurate than PCR. It provides very reliable inclusions and exclusion and thus is favored when enough DNA is available for assay. However, RFLP requires more DNA than PCR, and it takes more time to provide results. PCR is used more frequently in practice because it can be performed on smaller, older, and even damaged DNA samples, and the results are available in as little as one day. However, PCR is less resilient to contamination than RFLP, and may not provide amplifiable markers for all the loci tested.

The question of which assay to use has already been answered in the field. The advantages PCR holds over RFLP has made it the favored method in crimescene forensics. In these cases samples are very likely to be small and damaged, if they are recovered at all. Perhaps the biggest factor is the turnaround time. When we are trying to solve a case, we may not have the luxury of waiting the three weeks to three months RFLP requires. Thus, PCR is the more common method used first, and rightly so, with RFLP used only when needed.

The importance of properly handling DNA evidence cannot be overstated, as was shown in the OJ Simpson case where a potential mishandling of evidence caused most of the DNA evidence to be inadmissible due to “bungling” technicians. Thus, the prevention of contamination of DNA evidence from improper handling, or degradation due to improper storage, is paramount to the inclusion of DNA evidence in a court of law. Establishing a proper chain of custody of evidence is also required to document a record of who handled any piece of evidence, and when, thus making it harder to contaminate any evidence.

The evolution of what DNA evidence can be accepted in a court of law was a long and arduous one, starting with *Frye v. US* in 1923, and its "general acceptance" standard, which held for years until Rules of Evidence 702 finally overrode Frye in 1975. With the Colin Pitchfork case in 1987 came the first exoneration using DNA, and also the first murder conviction using DNA. In 1990, *US v. Matthew Two Bulls* expanded the requirements for including DNA in court to a 3-prong test, which was expanded in 1993 in *Daubert v Merrell Dow Pharmaceuticals* to a 5-prong test that emphasized the reliability of the technology, known error rates, and the proper performance of standardized tests. With 2003 came the conviction of Paul Robinson, the first conviction based on a "John Doe" warrant, containing only the DNA profile found at a crimescene, to "get around" the six year statute of limitations for rape. This approach was upheld in January 2010 by the US Supreme court.

With respect to who should provide DNA to databases, this is currently decided by individual states in the US. The authors of this report believe that only *convicted* criminals of any crime should be required to provide DNA samples to the CODIS database. We agree with the Supreme Court's ruling that criminals have a "lowered expectation of privacy" due to their status as convicted criminals. So in this case, society is allowed to infringe upon their privacy (to obtain a DNA sample) for the good of the majority. We should collect from all convicted criminals because the authors believe many criminals are likely to become repeat offenders. But when proponents of databases start insisting we include *everyone's* DNA, – arrestees, newborns, volunteers – the authors feel we start to demonstrate a lack of faith in the members of society to do good. This coupled with the logistical issues of collecting very large number of DNA profiles, leads to the following compromise of only convicted criminals DNA profiles residing in CODIS.

There should be no fear of medical predisposition data being hacked from CODIS, as our research shows that no such information resides in CODIS. The FBI has carefully chosen the 13 core loci used to create DNA fingerprints so that no medical information is reflected. Simply put, you can not get more information from CODIS than what is put in, and no medical information is put in. However, we agree that the original DNA sample should be destroyed after analyzying the 13 core loci, because further analysis of the sample could be done to obtain medical information. Currently, most states are ambiguous as to what to do with the original samples after being submitted into CODIS, so we agree with the state of Wisconsin who requires they be destroyed after obtaining a successful CODIS entry. Any inclusion of medical information in CODIS would severely fuels privacy concerns and weaken CODIS's ability to fulfill its forensic goals. It is the opinion of the authors that all states should adopt legislation similar to Wisconsin, which requires the destruction of DNA samples after obtaining CODIS information.